INTERNAL COMBUSTION ENGINE WITH NO_x ADSORBER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an internal combustion engine that includes a NO_x adsorber.

2. Background Art

The heavy-duty engine business is extremely competitive. Increasing demands are being placed on engine manufacturers to design and build engines that provide better engine performance, improved reliability, and greater durability while meeting more stringent emission and noise requirements. One approach to meet more stringent emission requirements is to utilize a NO_x adsorber. NO_x are believed to be an environmental hazard, and are created when combustion temperatures become excessive. NO_x are a particular concern in the turbocharged diesel engine.

A NO_x adsorber or NO_x trap is an aftertreatment device that stores or adsorbs NO_x under lean conditions. Periodically, the NO_x adsorber must be regenerated in order to continue collecting the NO_x emissions. Under rich conditions, the NO_x adsorber catalytically reduces the stored NO_x. In a typical arrangement for a diesel engine, a post injection of a reductant such as diesel fuel directly into the exhaust gas creates the rich conditions required for NO_x adsorber regeneration. In one arrangement, three seconds of regeneration are required for each one minute of NO_x adsorber operation.

For good regeneration, it is desired that the fuel (or other injected substance) be well mixed with the exhaust flow before entering the aftertreatment device. To improve the mixing, the current practice is to inject at an elbow, allow a long length of piping after the fuel is injected before entering the aftertreatment

device, or a combination of these or other mixing schemes. Further background information may be found in U.S. Patent Nos. 4,505,106; 6,442,933; 6,523,342; and 4,359,862.

For the foregoing reasons, there is a need to address the issue of mixing the reductant with the exhaust gas before entering the aftertreatment device.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide an improved internal combustion engine with a NO_x adsorber wherein the reductant is injected at a location slightly upstream, slightly downstream, or directly in the flow control valve to improve mixing of the reductant and the exhaust gas before entering the NO_x adsorber. The pressure drop across the flow control valve results in turbulence that improves mixing of the injected liquid or gas reductant with the engine exhaust gas. Advantageously, good mixing can be achieved in a relatively short distance, which may result in aftertreatment device performance benefits and packaging benefits. The flow control valve controls the relative amounts of exhaust gas mixture that flow to the NO_x adsorber and that are diverted to an alternate path.

In carrying out the above object, an internal combustion engine is provided. The internal combustion engine has a plurality of cylinders. The engine includes an intake manifold and an exhaust manifold. The engine further comprises a first exhaust path for receiving and routing exhaust gases, a first NO_x adsorber located in the first exhaust path, and a second exhaust path for receiving and routing exhaust gases. The engine further comprises a flow control valve between the exhaust manifold and the first and second exhaust paths for controlling the relative amounts of exhaust gas flowing through the first and second exhaust paths. The engine further comprises a first injector for injecting a reductant into the exhaust gas stream. The first injector is located so as to inject the reductant at a location adjacent to the flow control valve to cause mixing of the reductant and the exhaust gas and to allow regeneration of the first NO_x adsorber.

It is appreciated that the reductant may or may not be fuel. It is appreciated that the flow control valve may be implemented in any suitable way that controls the relative amounts of exhaust gas flowing through the first and second exhaust paths. That is, the term "flow control valve" encompasses any arrangement using at least one flow control valve for controlling the relative amounts of exhaust gas flowing through the first and second exhaust paths. It is appreciated that the reductant injection adjacent to the flow control valve may occur at a location slightly upstream, slightly downstream, or directly in the flow control valve. Certain valve and injector arrangements route a lesser amount of exhaust gas to the NO_x adsorber during regeneration than during normal operation. This approach allows a corresponding reduced amount of reductant to be injected. In a case where the reductant is fuel, such an approach limits the negative impact on fuel economy associated with the NO_x adsorber regeneration process.

In some embodiments, the engine further comprises a second NO_x adsorber located in the second exhaust path, and a second injector for injecting a reductant into the exhaust gas stream. The second injector is located so as to inject the reductant at a location adjacent to the control valve to cause mixing of the reductant and the exhaust gas and to allow regeneration of the second NO_x adsorber. Using multiple NO_x adsorbers reduces the overall NO_x level passed to the environment because only one NO_x adsorber is regenerated at a time while remaining adsorber(s) remain active, and only a small portion of the total exhaust gas is routed to the regenerating NO_x adsorber while routing the larger remaining portion of the exhaust gas to the active NO_x adsorber(s). Again, it is appreciated that the invention comprehends the concept of one or more NO_x adsorbers and various flow control valve arrangements that control the relative amounts of exhaust gas flowing through the various exhaust paths with a flow control valve improving the mixing of the exhaust gas and the reductant.

Further, in carrying out the present invention, an internal combustion engine with a plurality of cylinders is provided. The engine includes an intake manifold and an exhaust manifold. The engine further comprises a first exhaust path for receiving and routing exhaust gases, a first NO_x adsorber located in the first

exhaust path, and a second exhaust path for receiving and routing exhaust gases. The engine further comprises a first flow control valve between the exhaust manifold and the first exhaust path and a second flow control valve between the exhaust manifold and the second exhaust path. The first and second flow control valves control the relative amounts of exhaust gas flowing through the first and second exhaust paths. The engine further comprises a first injector for injecting a reductant into the exhaust gas stream. The first injector is located so as to inject the reductant at a location adjacent to the first flow control valve to cause mixing of the reductant and the exhaust gas and to allow regeneration of the first NO_x adsorber.

In some embodiments, the engine further comprises a second NO_x adsorber located in the second exhaust path and a second injector. The second injector is for injecting a reductant into the exhaust gas stream. The second injector is located so as to inject the reductant at a location adjacent to the second flow control valve to cause mixing of the reductant and the exhaust gas and to allow regeneration of the second NO_x adsorber.

Still further, in carrying out the present invention, a method is provided. The method is for use in an internal combustion engine including a first NO_x adsorber and a first injector. The method comprises operating the engine in an active mode, and, subsequently, operating the engine in a regenerative mode. In the active mode, exhaust gas flows through the first exhaust path and then through the first NO_x adsorber such that the first NO_x adsorber adsorbs NO_x from the exhaust gas. In the regenerative mode, a flow control valve causes a reduced amount of the exhaust gas to flow through the first exhaust path and through the first NO_x adsorber and the reductant is injected into the reduced amount of the exhaust gas at a location adjacent to the flow control valve. This causes mixing of the reductant and the exhaust gas such that the first NO_x adsorber catalytically reduces the previously adsorbed NO_x to regenerate the first NO_x adsorber.

Still further, in carrying out the present invention, a method is provided. The method is for use in an internal combustion engine including a first NO_x adsorber and a first injector, and a second NO_x adsorber and a second injector.

The method comprises operating the engine in an active mode, subsequently, operating the engine in a first regenerative mode, and, subsequently, operating the engine in a second regenerative mode. In the active mode, exhaust gas flows through the first exhaust path and through the first NO_x adsorber such that the first NO_x adsorber adsorbs NO_x from the exhaust gas. Further, in the active mode, exhaust gas flows through the second exhaust path and through the second NO_x adsorber such that the second NO_x adsorber adsorbs NO_x from the exhaust gas.

In the first regenerative mode, a flow control valve causes a reduced amount of the exhaust gas to flow through the first exhaust path and through the first NO_x adsorber. The reductant is injected into the reduced amount of the exhaust gas at a location adjacent to the flow control valve. This causes mixing of the reductant and the exhaust gas such that the first NO_x adsorber catalytically reduces the previously adsorbed NO_x to regenerate the first NO_x adsorber.

In the second regenerative mode, a reduced amount of the exhaust gas flows through the second exhaust path and through the second NO_x adsorber. The reductant is injected into the reduced amount of the exhaust gas at a location adjacent to a flow control valve. This causes mixing of the reductant and the exhaust gas such that the second NO_x adsorber catalytically reduces the previously adsorbed NO_x to regenerate the second NO_x adsorber.

In a preferred method, the second adsorber remains active while the first adsorber is regenerated in the first regenerative mode. Further, preferably, the first adsorber remains active while the second adsorber is regenerated in the second regenerative mode.

The above object and other objects, features, and advantages of the present invention are readily apparent from the following detailed description of the preferred embodiments when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates an engine of the present invention including a single flow control valve and a single NO_x adsorber;

FIGURE 2 illustrates an engine of the present invention including two flow control valves and a single NO_x adsorber;

FIGURE 3 illustrates an engine of the present invention including a single flow control valve and two NO_x adsorbers;

FIGURE 4 illustrates an engine of the present invention including two flow control valves and two NO_x adsorbers;

FIGURE 5 illustrates a method of the present invention; and

FIGURE 6 illustrates a method of the present invention utilizing first and second NO_x adsorbers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates an internal combustion engine including an engine block 10 with a plurality of cylinders 12. The illustrated engine is a compression-ignition internal combustion engine such as a heavy-duty diesel engine. Cylinders 12 receive pressurized fuel from a fuel supply in a known manner. The engine includes an intake manifold 14 and an exhaust manifold 16. A flow control valve 18 is located between exhaust manifold 16 and first and second exhaust paths 20 and 22, respectively. Flow control valve 18 controls the relative amounts of exhaust gas flowing through the first exhaust path 20 and the second exhaust path 22. A NO_x adsorber 24 is located in first exhaust path 20. An injector 26 is for injecting a reductant such as fuel into the exhaust gas stream. Injector 26 injects the reductant at a location adjacent to flow control valve 18 to cause mixing of the reductant and the exhaust gas and to allow regeneration of NO_x adsorber 24.

In operation, when NO_x adsorber 24 is active, substantially all exhaust flow is directed by flow control valve 18 to first exhaust path 20 and in the presence of the lean exhaust gas mixture, NO_x adsorber 24 adsorbs or traps NO_x. Periodically, NO_x adsorber 24 must be regenerated. Regeneration takes place by injector 26 injecting the reductant into first exhaust path 20 to create a richer exhaust gas mixture that causes NO_x adsorber 24 to catalytically reduce the stored NO_x. During the regeneration process, flow control valve 18 directs only a reduced portion of the total exhaust gas flow to first exhaust path 20 while diverting the remaining portion of exhaust gas flow to second exhaust path 22. In this way, the amount of reductant required to create the rich mixture for regeneration is reduced. Particularly, when the reductant is fuel, this approach reduces the negative effects on fuel economy associated with regeneration of NO_x adsorber 24. It may be desirable to modify the fuel injection strategy during regeneration to reduce the amount of NO_x diverted through second exhaust path 22 where there is no adsorber.

Figure 2 illustrates an embodiment similar to the embodiment of Figure 1 but including first and second control valves 30 and 32, respectively. Flow control valves 30 and 32 control the relative amounts of exhaust gas flowing through first exhaust path 20 and second exhaust path 22.

Figure 3 illustrates an embodiment including a single flow control valve 18 and first and second NO_x adsorbers 24 and 36, respectively. First and second injectors 26 and 34, respectively, are associated with the first and second NO_x adsorbers 24 and 36, respectively. Flow control valve 18 controls the relative amounts of exhaust gas flowing through first exhaust path 20 and second exhaust path 22. This embodiment allows NO_x adsorbers 24 and 36 to be alternately regenerated such that the main portion of the exhaust gas flow is always being treated by one or the other NO_x adsorber. For example, when both NO_x adsorber 24 and NO_x adsorber 36 are active, flow control valve 18 may pass half of the total exhaust flow to each of first and second exhaust paths 20 and 22, respectively. When NO_x adsorber 24 requires regeneration, flow control valve 18 may divert a majority of the exhaust gas to NO_x adsorber 36 for aftertreatment while sending only a reduced portion of the exhaust gas flow along first path 20 to NO_x adsorber 24.

In this way, the amount of reductant injected by injector 26 to create the required rich mixture is reduced which has significant effects on fuel economy when the reductant is fuel.

Figure 4 illustrates an embodiment similar to the embodiment of Figure 3 but including first and second control valves 30 and 32, respectively. Flow control valves 30 and 32 control the relative amounts of exhaust gas flowing through the first exhaust path 20 and second exhaust path 22.

Figure 5 illustrates a method of the present invention. At block 40, the engine is operated in an active mode where exhaust gas flows through a first exhaust path and through a first NO_x adsorber such that the first NO_x adsorber adsorbs NO_x from the exhaust gas. At block 42, subsequently, the engine is operated in a regenerative mode. In the regenerative mode, a reduced amount of the exhaust gas flows through the first exhaust path and through the first NO_x adsorber, and the reductant is injected into the reduced amount of the exhaust gas at a location adjacent to a flow control valve to cause mixing of the reductant and the exhaust gas. This causes the first NO_x adsorber to catalytically reduce the previously adsorbed NO_x to regenerate the first NO_x adsorber.

In Figure 6, a method involving two NO_x adsorbers is illustrated. At block 44, the engine is operated in the active mode, adsorbing NO_x with both NO_x adsorbers. At block 46, the engine is operated in a first regenerative mode to regenerate the first NO_x adsorber by injecting reductant adjacent to a flow control valve while the second NO_x adsorber remains active. At block 48, the engine is operated in a second regenerative mode to regenerate the second NO_x adsorber by injecting reductant adjacent to a flow control valve while the first NO_x adsorber remains active.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are

words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.